Integrated Vector Management in Cambodia: *Operational Integration for Malaria Elimination*[1]

[1]Gates Foundation Funding: *Integrated Vector Management: Operational Integration for Malaria Elimination*

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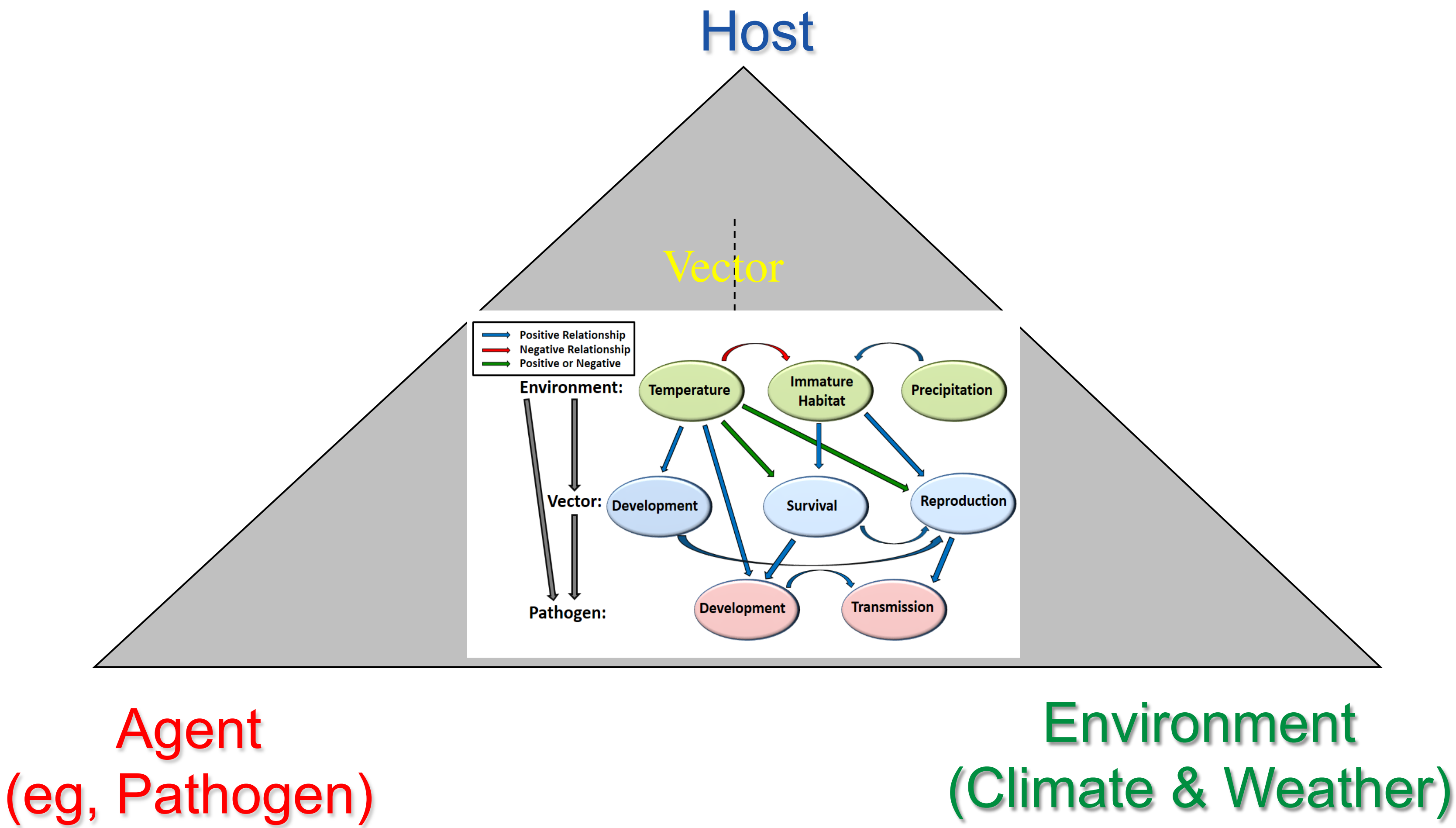
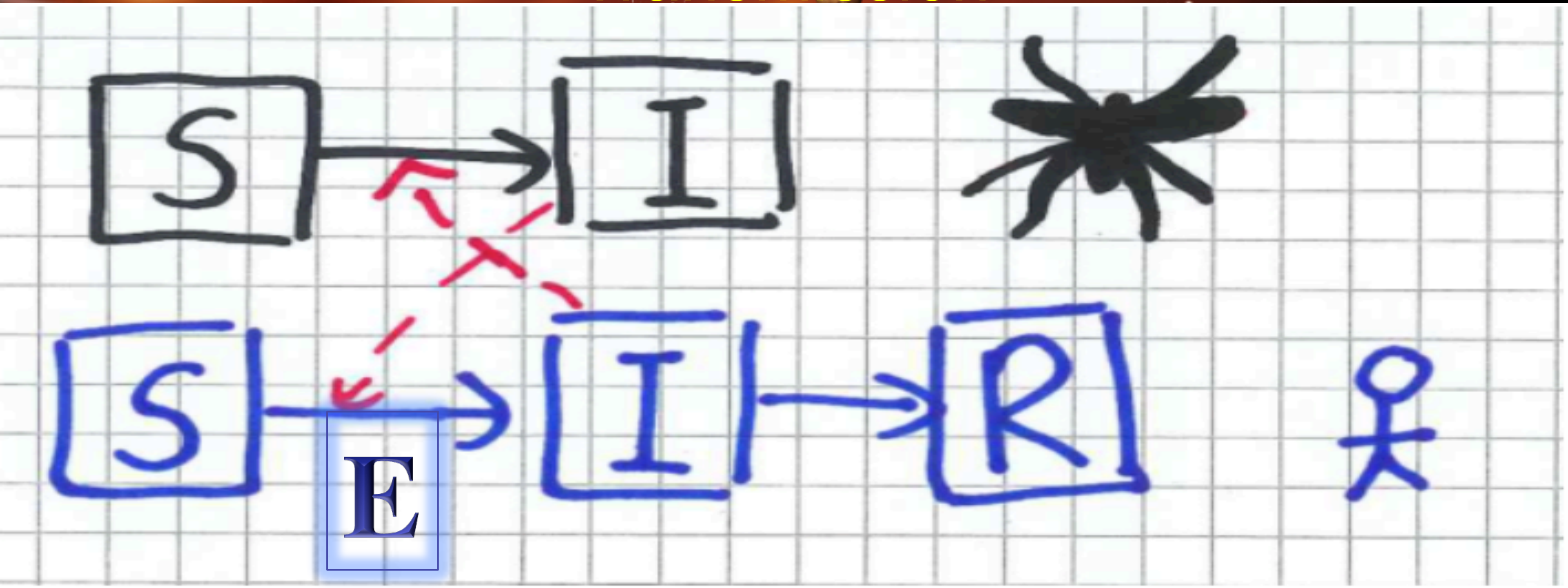
Epidemiologic Triangle of Disease (Vector-borne Diseases)

A multi-factorial relationship between hosts, agents, vectors and environment



Morin 2014

1915 Ross Model For Vector-borne Malaria Transmission



$$\frac{dI_h}{dt} = \alpha \lambda \omega I_m (1 - I_h) - \gamma I_h$$

$$\frac{dI_m}{dt} = \alpha v I_h (1 - I_m) - m I_m$$

Ross, Ronald. "Some a priori pathometric equations." British Medical Journal 1.2830 (1915): 546 http://equationsofdisease.wordpress.com

Vectorial Capacity

$$VC = \frac{ma^2bp^N}{-\log(p)}$$

variable	definition
m	Mosquito:vertebrate density
a	Man biting rate of mosquito (alternatively, contact rate)
b	Vector competence (% mosquitoes that will become infectious)
p	Mosquito mortality (average lifespan)
N	EIP (time it takes for virus to be transmitted by a mosquito)

Figure 5: Vectorial Capacity (VC) equation and variable definitions.

Impacts of Temperature on Vector Life Cycle

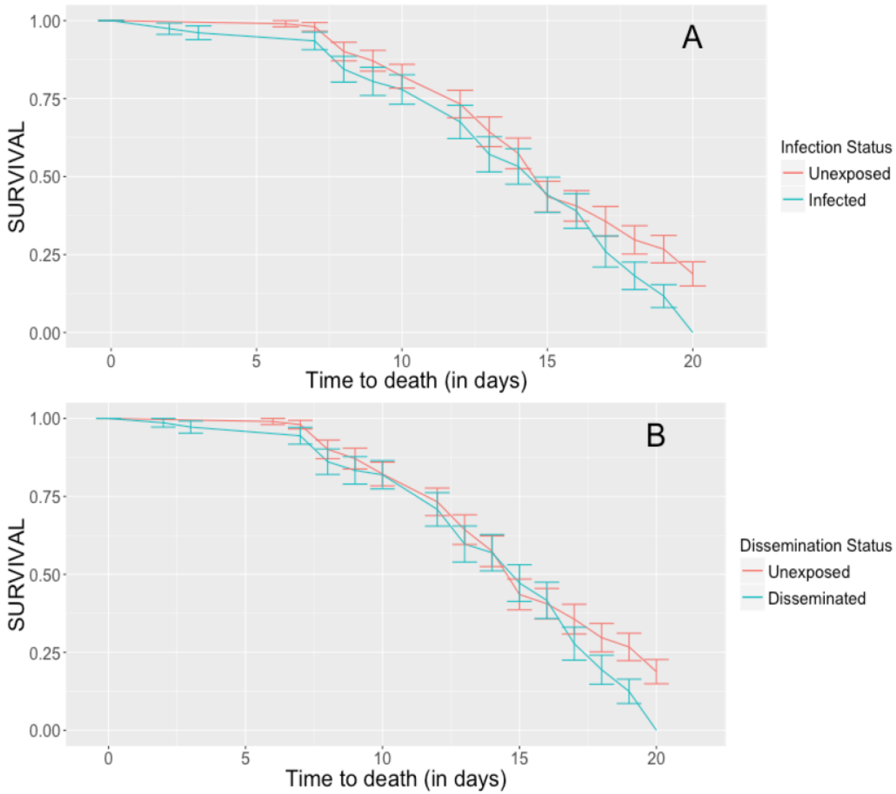


Figure 6 (from Christofferson & Mores 2016): Survival curves for comparisons of A) unexposed to infected mosquitoes at 30°C and B) unexposed to mosquitoes with a disseminated infection were significantly different.

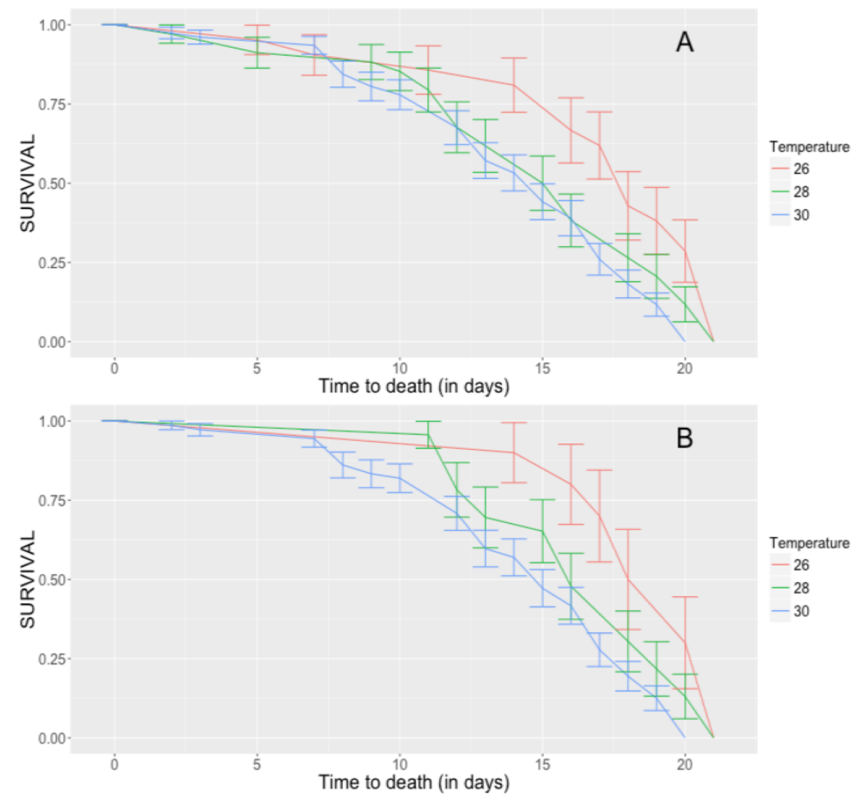


Figure 7 (from Christofferson & Mores 2016): Survival curves for comparisons of A) infected mosquitoes across all three temperatures and B) mosquitoes with a disseminated infection across all three temperatures. Significant differences were found only between 26°C (red) and 30°C (blue) in both cases.

Potentially, An Increased Risk of Transmission

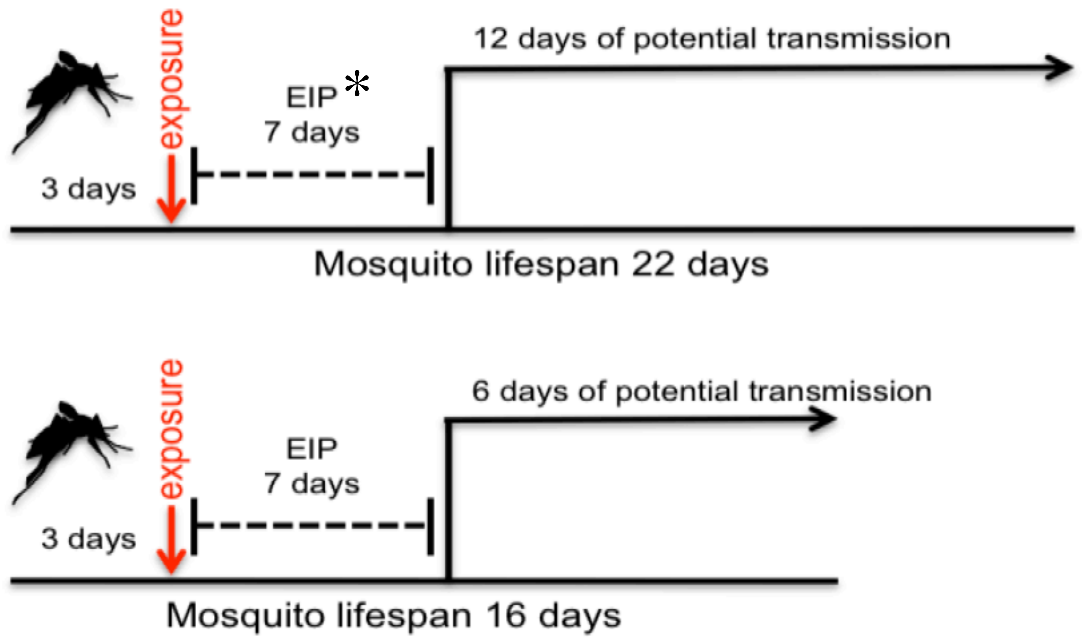
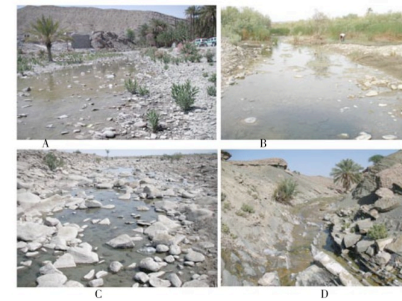


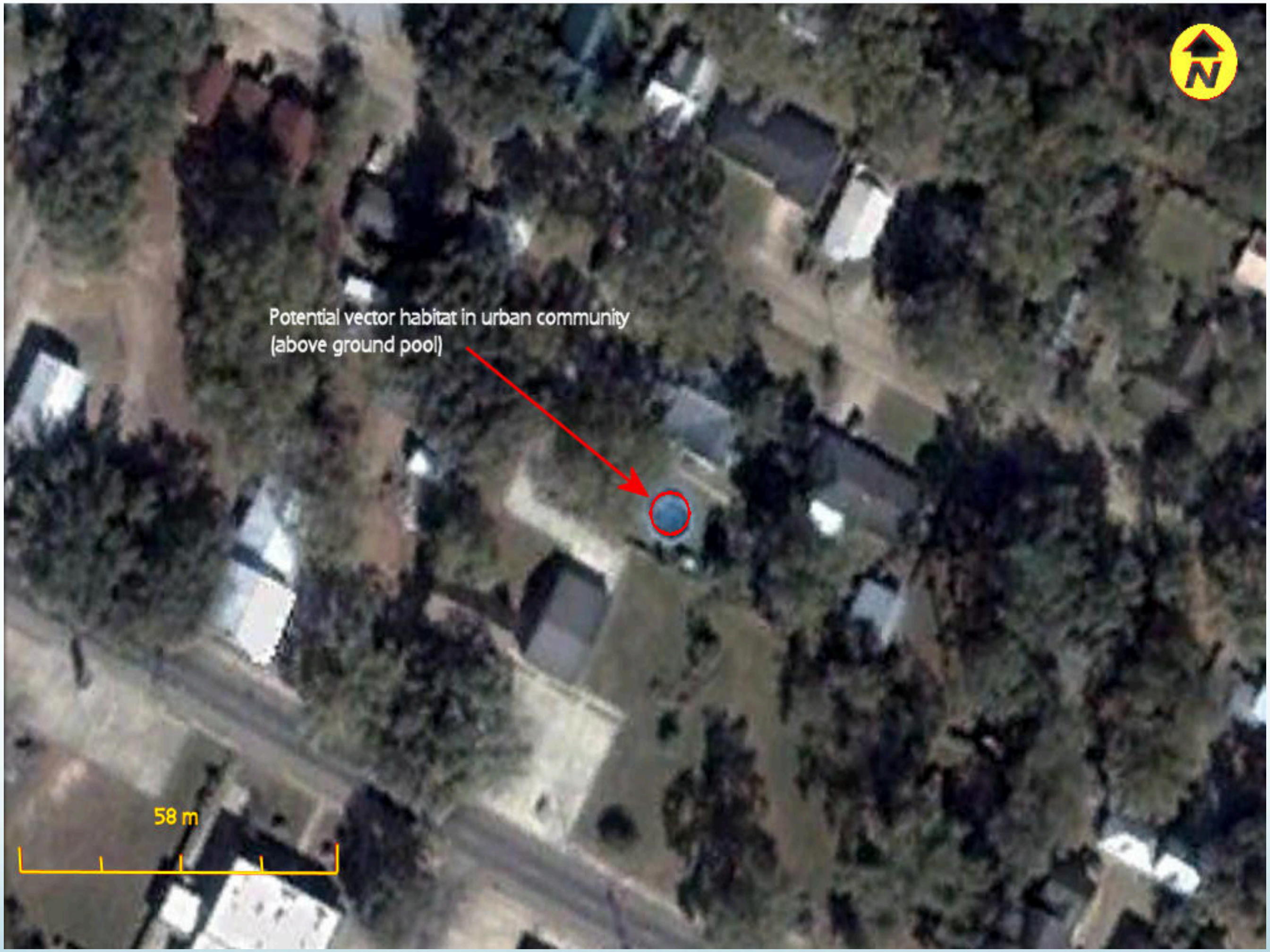
Figure 8 (from Christofferson & Mores 2016): Schematic demonstrating the impact of mosquito mortality on the cumulative transmission potential of an arbovirus.

*Extrinsic Incubation Period (EIP). This process is known to be influenced by both intrinsic (such as viral strain and/or mosquito population) and extrinsic factors (such as temperature and humidity)

Places that Produce *Anopheles* Mosquitoes



Backyard Swimming Pools Los Angeles County California.



Strengths Of Satellite Observations

Measures environmental state functions important to vector & disease life cycles (within vector)
Precipitation, soil moisture, temperature, vapor pressure deficits, wet/dry edges, solar radiation….

***But also the interfaces as process functions*:**
Land use/cover mapping; Ecological functions/structure, canopy cover, species, phenology, aquatic plant coverage…..

And provides a Spatial Context
Spatial coverage & topography – local, regional & global…

Lastly, but perhaps the greatest strength:
Provides a time series of measurements

A Ecological Thermodynamic Paradigm

☀ θΔ ics 🌎

The epidemiological equations (processes) can be adapted and modified to *explicitly incorporate environmental factors and interfaces*

Remote sensing can be used to measure or evaluate or estimate *both environment (state functions) and interface (process functions).* The products of remote sensing must be expressed in a way they *can be integrated directly into the epidemiological equations.* The desired logical structures must be consistent with thermodynamic and with probabilistic frameworks.

Challenges

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Satellite Data

- repeat frequency & spatial resolution
- spectral bands available
- clouds
- life cycle
- cost
- data availability & timeliness of delivery

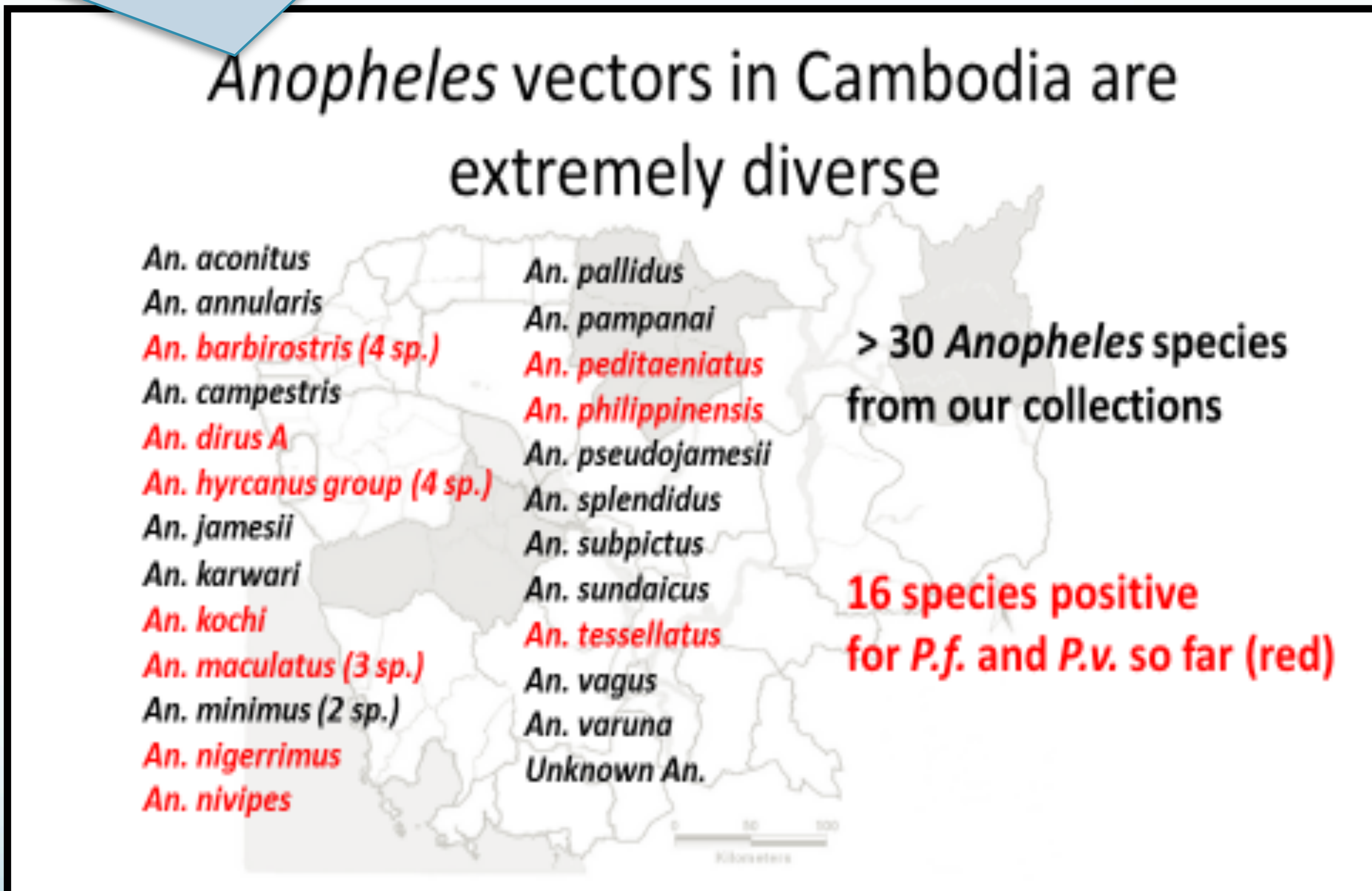
Public Health & Epidemiology

- availability of data & various sampling issues
- difficulty in getting access to sampling areas
- cost
- understanding of the data provided by satellites
- ***Define & quantify the multi-factorial relationships between hosts, agents, vectors and environment***

Environmental Surveillance and Monitoring System

Robert J. Novak, PhD
University of South Florida
College of Public Health
Department of Global Health

Plasmodium falciparum is a protozoan parasite, one of the species of Plasmodium that cause malaria in humans.
(P. vivax was also present in Cambodia)

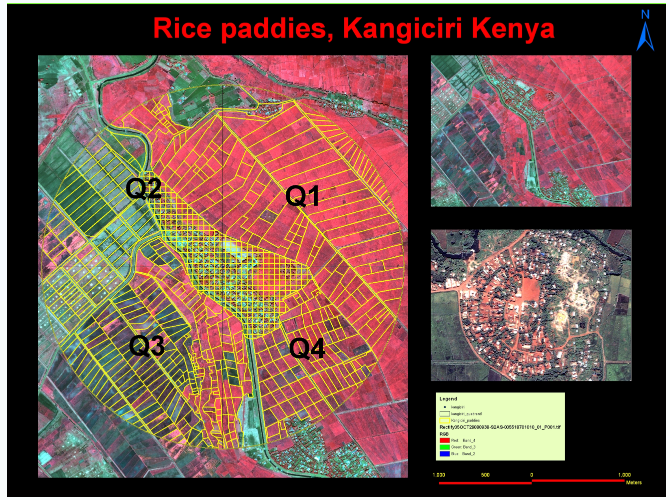


DELIVERABLES

1. To develop an "off the shelf" user friendly Product for "Environmental Surveillance and Monitoring using GIS, remote sensing technologies, providing for the basic elements applicable to multiple landscapes and geographic areas (global) to provide near real time information for decision makers at all levels of Government and malaria control operations.
2. The Product will provide the means for overlaying a measured and changeable grid for enhance logistics for surveillance and sampling from high resolution satellite data and the ability to create associated data files to specific areas of concern.
3. The product will also provide a user friendly means to identify and monitor aquatic and terrestrial mosquito habitats and create "unique habitat signature" for Anopheles species (habitat signatures to locate new and unknown habitats.
4. The Product will also provide "user friendly" means to create digital elevation, climate and vegetation models to locate and monitor areas of concern for malaria transmission.
5. The Product using remote sensing technology provides the means to detect plums of CO_2 and ammonia in 20 to 60 cm^2 units to locate areas of high attractive risk to human hosts.
6. The product will include open data architecture to accommodate multiple users and databases.
7. This new signature ability is combined with UAV (Drone) technology developed for mosquito surveillance and control to fine-tune habitat signatures regarding temporal habitat variations.

Key Input Elements of the Cyber System Platform.

Community Based = Evidence Based Data

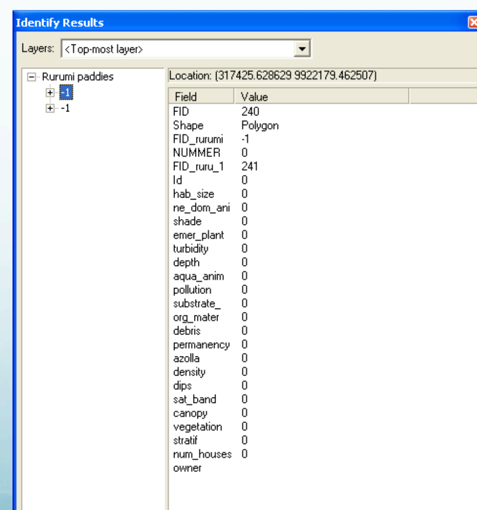


0.6m QuickBird
Image with digitized grid

Entomological Data Menu
- Adult Density
- Indoor Biting Collections
- EIR
- Larval Abundance
- Aquatic habitats
- Habitat productivity

Parasitology Data Menu
- Thick smear
- plasmodium type
- therapy

A single location multiple data menu system



Family Information Menu
- House location
- House type
- Children
- Animals
- Roof type
- Cell phone number

Environmental Data Menu
- flood pattern
- shade
- containers
- water sources

Mosquito Control Menu
- indoor type
- outdoor
- timing

Personal Protection Menu
- bed nets
- usage
- types
- location

Creating a Spectral Habitat Signature

0.2 – 0.6 m^2
Pixel

Spectral Band	Purpose
Coastal Blue	Vegetation and water depth based on chlorophyll
Blue	Vegetative analysis based on chlorophyll
Green	Plant vigor analysis
Yellow	Plant vigor on land and in the water
Red	Vegetation discrimination, soils, geology
Red Edge	Plant vigor
Near Infrared 1	Moisture content, plant biomass
Near Infrared 2	Moisture content, plant biomass

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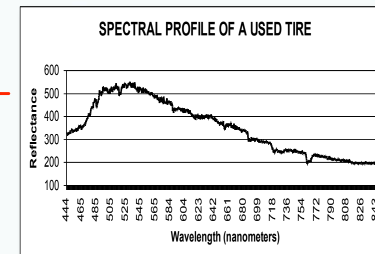
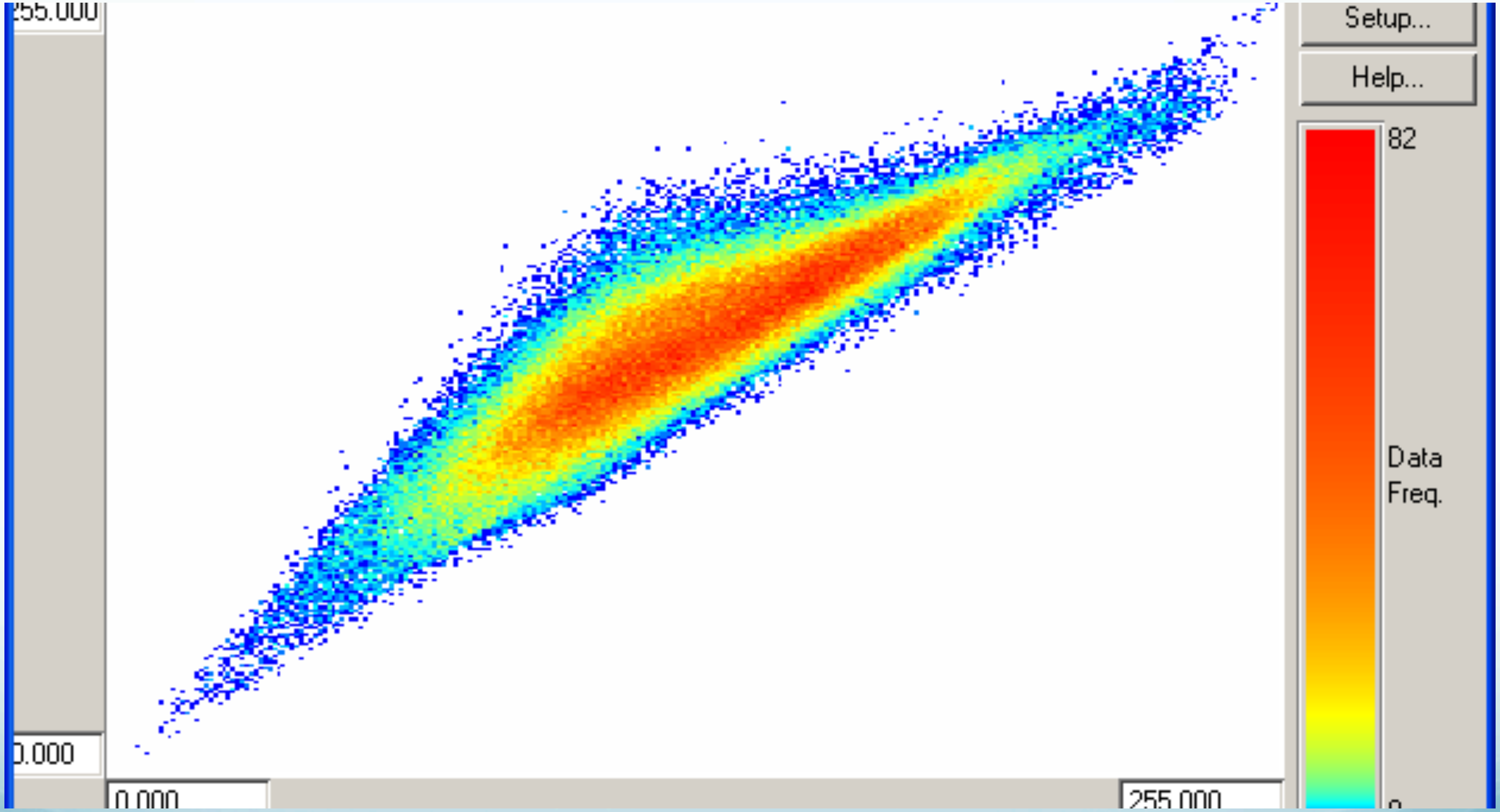


Spectral Signature

The "Intelligent" Pixel

Spectral signature of the a larval habitat at Dienkoa study site



Papoli Uganda Integrated Vector Management (IVM) Surveillance Study

Papoli Anopheles Hot Spots: Week 1

Legend

Total Anopheles
- 1
- 2 - 3

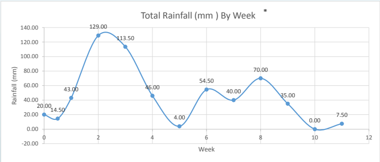
Zone
- ZONE A
- ZONE B
- ZONE C
- ZONE D

Image courtesy of the Digital Globe Foundation

Weekly Papoli Environmental Data: 3/13/16 – 6/11/16

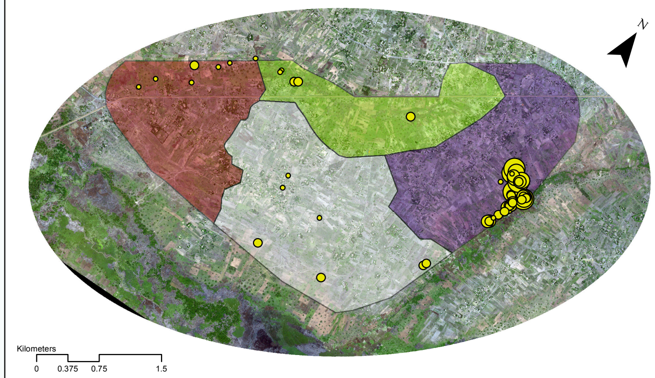
Month	Avg_Rain_Day_mm	Rain_Total_mm	Avg_humidity	Avg_maxtemp_C
March	1.816	34.5	40.79	33.74
April	11.183	335.5	62.40	29.20
May	6.44	199.5	62.58	28.58
June				
July				
August				
Sept				

Week	Avg_Rain_Day_mm	Rain_Total_mm	Avg_humidity	Avg_maxtemp_C
Pre (0)	2.86	20.00	36.86	35.29
Training (0.5)	2.07	14.50	44.14	33.14
1	6.14	43.00	47.86	31.00
2	18.43	129.00	58.43	29.43
3	16.21	113.50	59.14	30.29
4	6.57	46.00	65.00	29.29
5	0.57	4.00	66.71	28.29
6	7.79	54.50	68.29	28.57
7	5.71	40.00	65.43	28.71
8	10.00	70.00	60.57	27.71
9	5.00	35.00	60.71	28.86
10	0.00	0.00	49.14	30.29
11	1.07	7.50	49.14	30.14



*Week 0 is the Week Prior to Arrival
*Week 0.5 is the Week of Training

Papoli Anopheles Hot Spots: Week 5



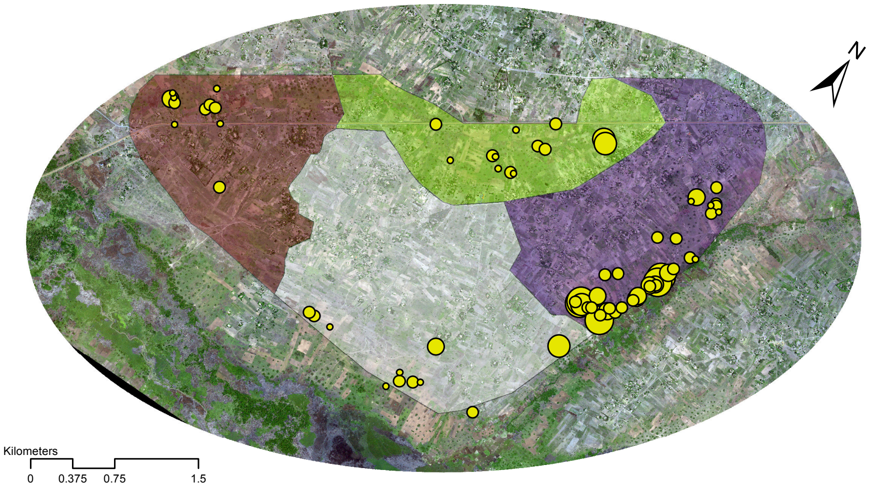
Legend

Total Anopheles
- 1
- 2 - 5
- 6 - 10
- 11 - 15
- 16 - 52

Zones
- ZONE A
- ZONE B
- ZONE C
- ZONE D

Image Courtesy of the Digital Globe Foundation

Papol Anopheles Hot Spots: Week 11



Legend

Total Anopheles

- 1
- 2 - 5
- 6 - 10
- 11 - 15
- 16 - 37

Zones

- ZONE A
- ZONE B
- ZONE C
- ZONE D

Images courtesy of the Digital Globe Foundation

Weekly Papoli Environmental Data: 3/13/16 – 6/11/16

Month	Avg_Rain_Day_mm	Rain_Total_mm	Avg_humidity	Avg_maxtemp_C
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June				
July				
August				
Sept				

Week	Avg_Rain_Day_mm	Rain_Total_mm	Avg_humidity	Avg_maxtemp_C
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3	16.21	113.50	59.14	30.29
4	6.57	46.00	65.00	29.29
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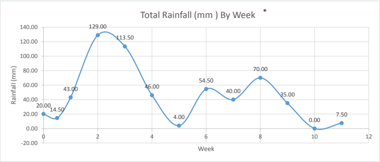
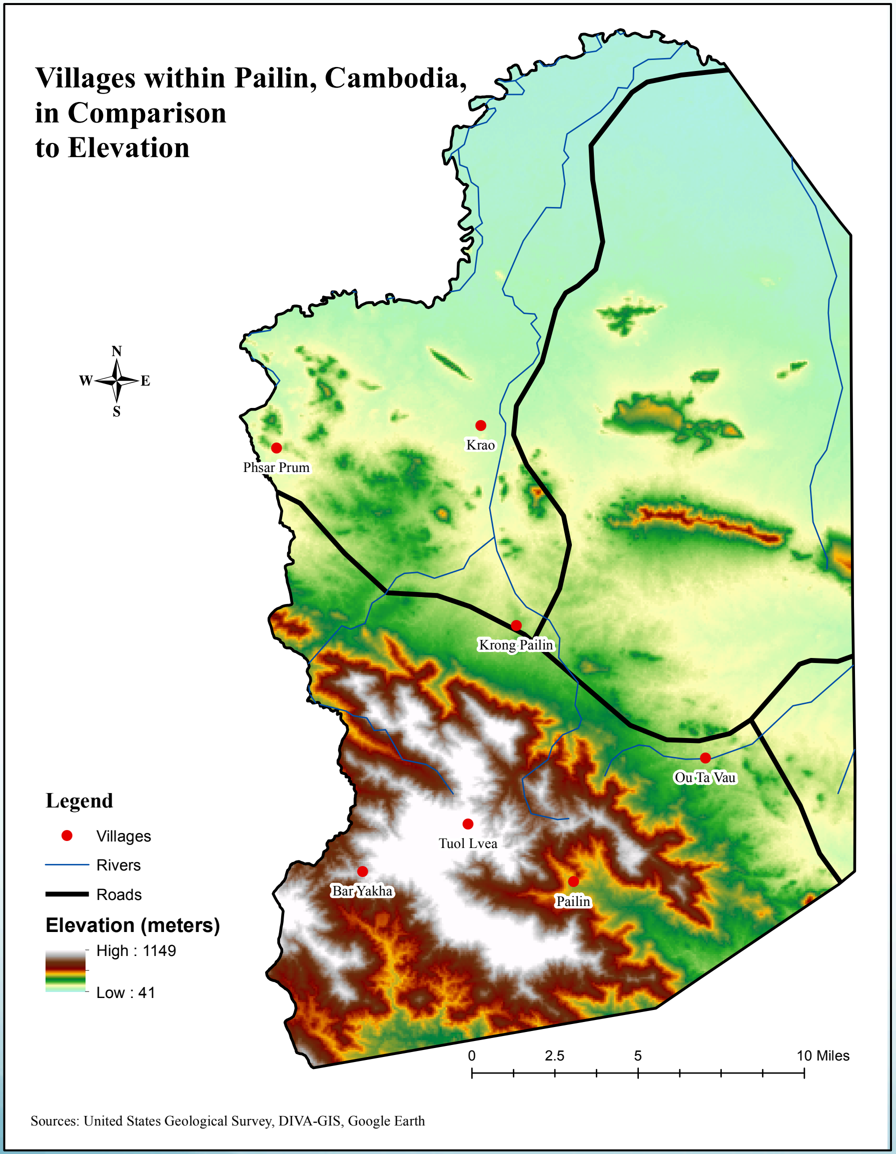
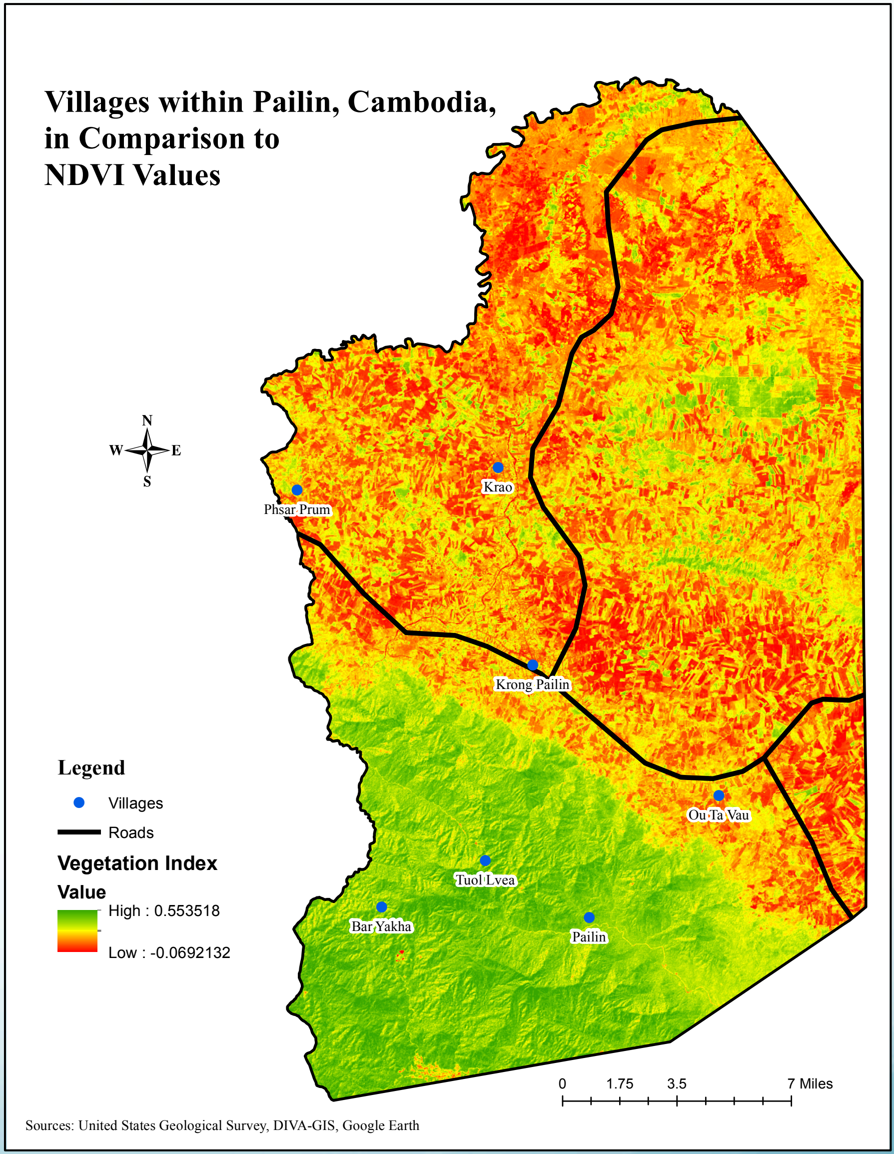


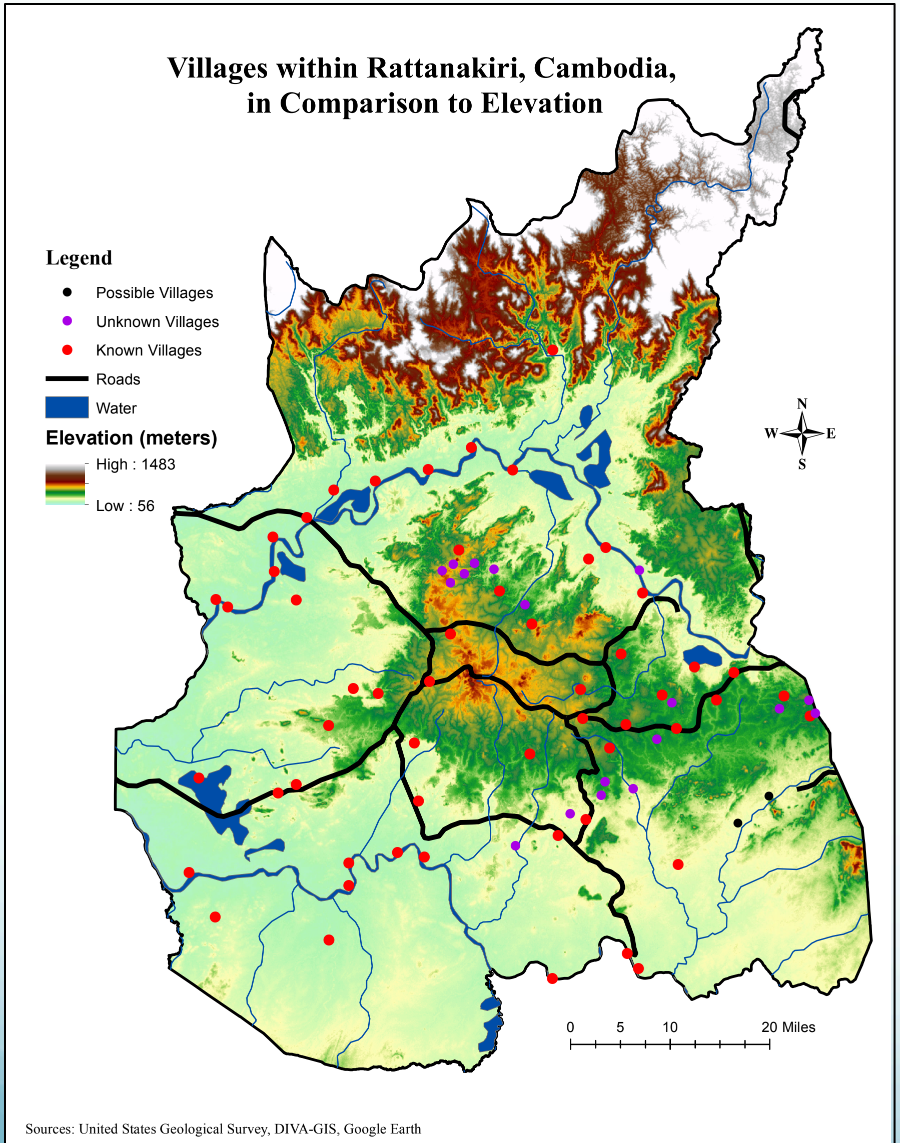
*Week 0 is the Week Prior to Arrival
*Week 0.5 is the Week of Training

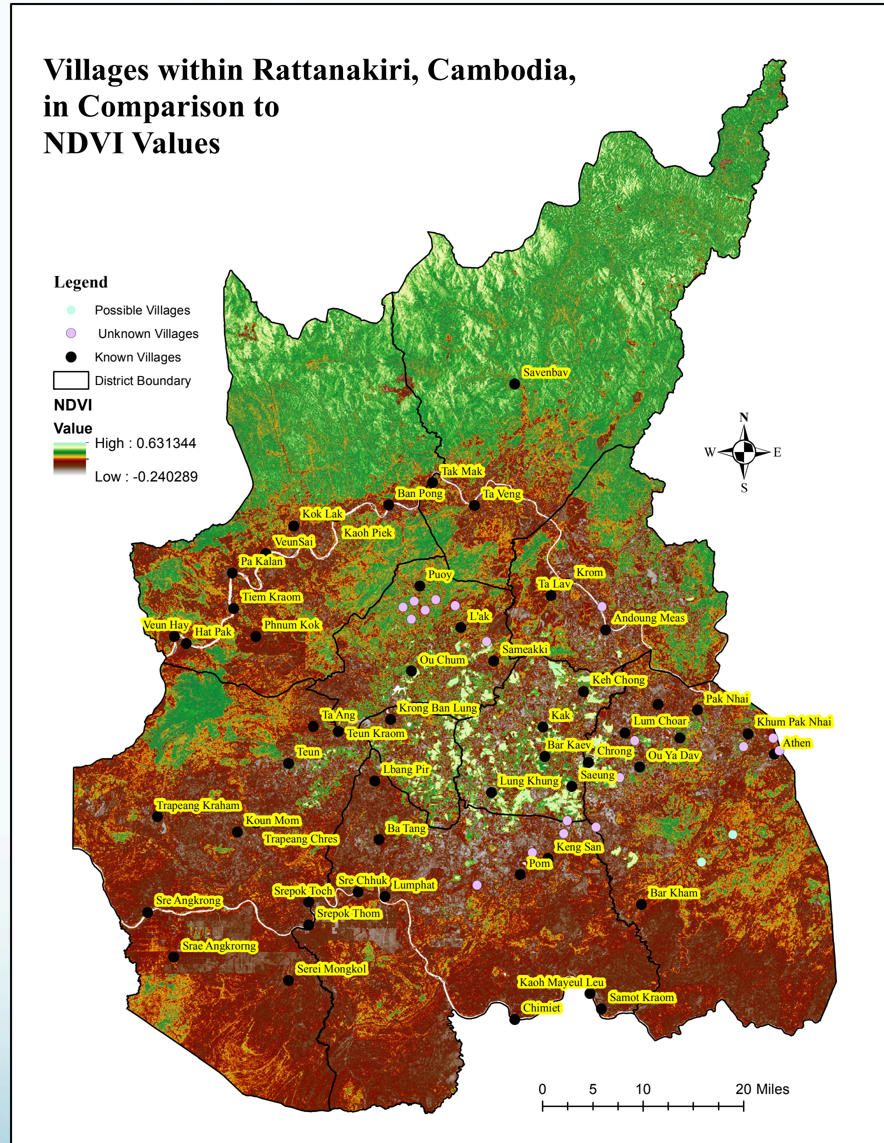
Pailin Cambodia





RattanKiri Elevation and NDVI Maps



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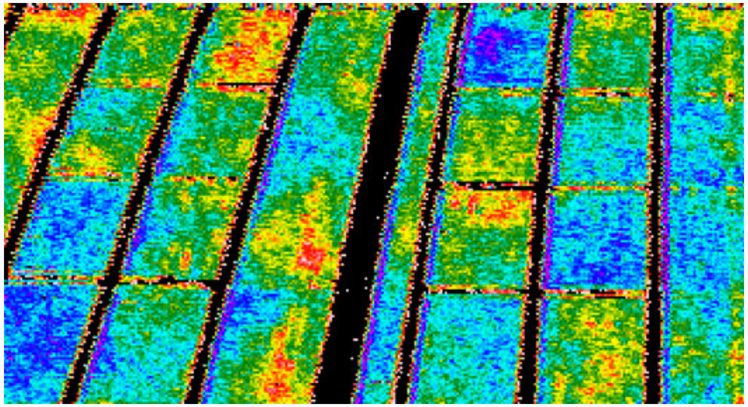
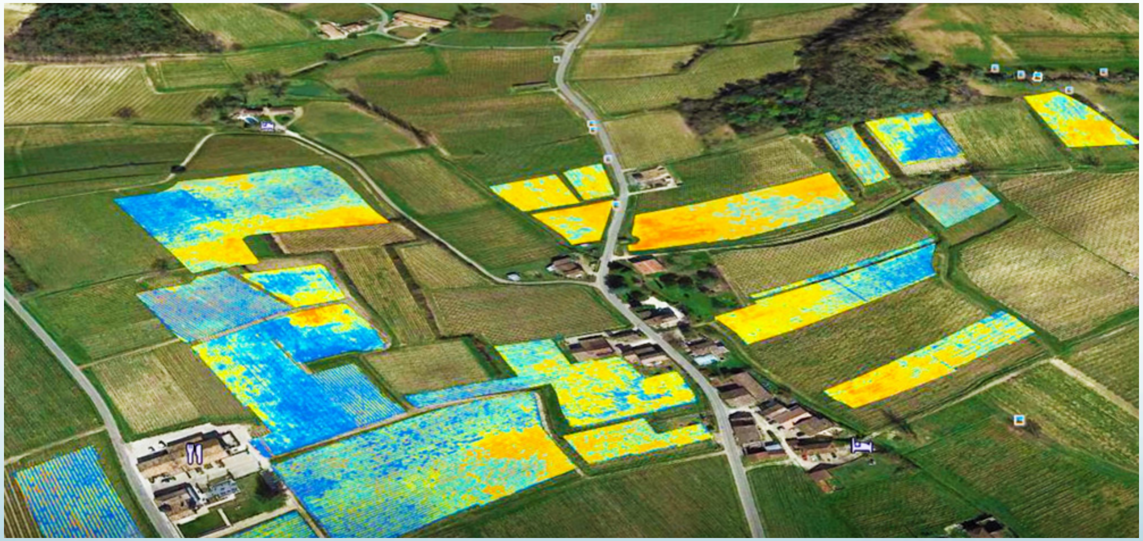
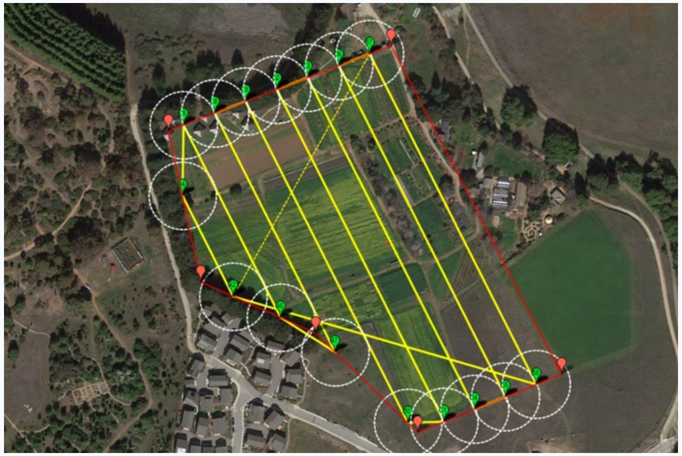
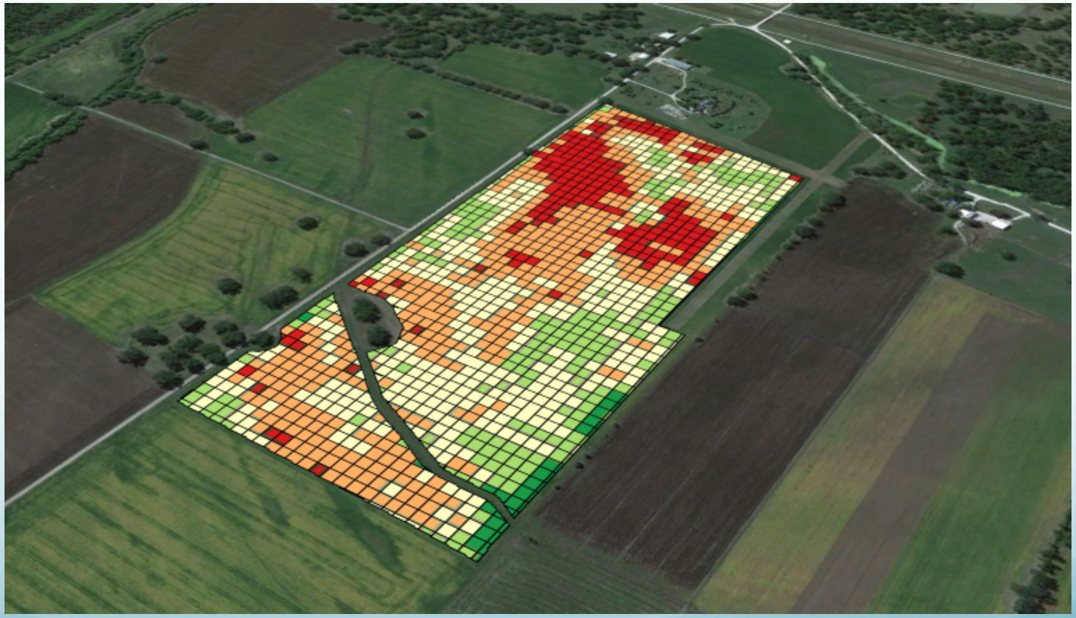





1
5
4
2
3





HyspIRI Decadal Survey Mission

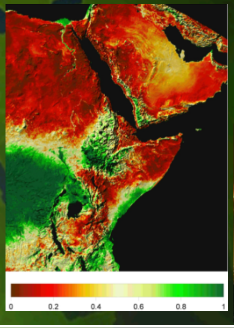
Key Science and Science Applications

Climate: Ecosystem biochemistry, condition & feedback; evapotranspiration
Ecosystems: Global biodiversity, plant functional types, physiological condition, and biochemistry
Fires: Fuel status; fire frequency, severity, emissions, and patterns of recovery globally
Coral reef and coastal habitats: Global composition and status
Volcanoes: Eruptions, emissions, regional and global impact
Geology and resources: Global distributions of surface mineral resources

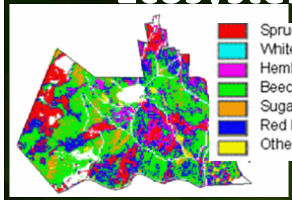
Mission Urgency

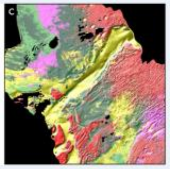
The HyspIRI science and applications objectives are critical today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct broadcast.

Evapo-transpiration



Ecosystems

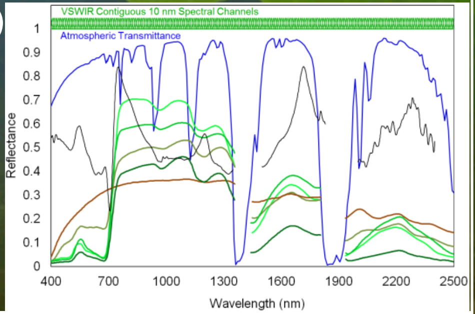




Measurement

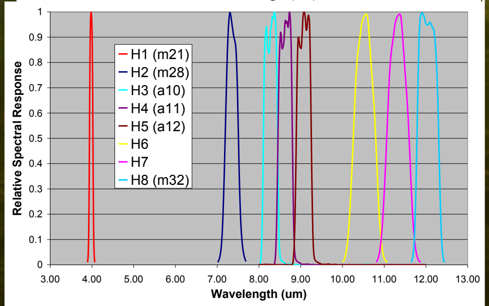
Imaging Spectrometer (VSWIR)

- 380 to 2500nm in 10nm bands
- 60 m spatial sampling
- 19 days revisit
- Global land and shallow water

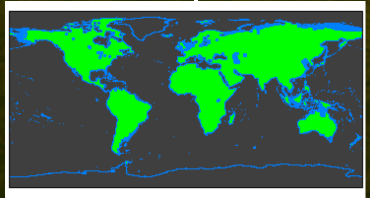


Thermal Infrared (TIR):

- 8 bands between 4-12 µm
- 60 m spatial sampling
- 5 days revisit; day/night
- Global land and shallow water



IPM-Low Latency data subsets



Mission Concept Status

Preliminary Draft Program Level 1 Requirements: Stable
Payload: Imaging Spectrometer, Thermal Infrared Imager, and IPM-Low Latency subsets
Spacecraft: RFI responses in
Payload: TBD - JPL/GSFC concept
Launch Vehicle: Small class
Launch date: ≥2024
Mission: Class C, 3-year baseline
Trajectory or Orbit: LEO, Sun sync.
S/C & Instrument Mass: 686kg (30% margin)
S/C & Instrument Power: 708W (45% margin against peak)
Mission Cost (FY12 est.): $506M incl. 30% reserve except for LV

The HyspIRI mission concept is mature and stable with excellent heritage, low risk and modest cost.

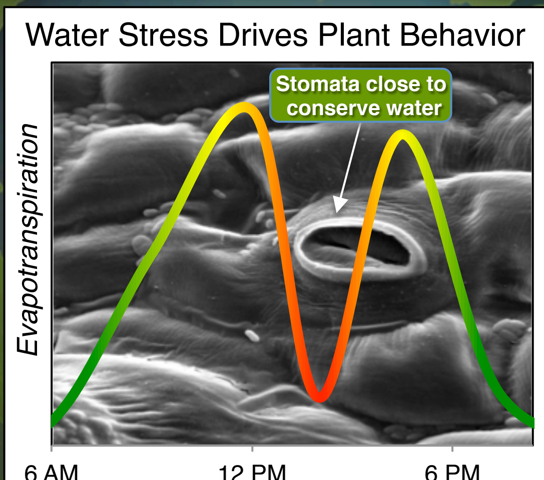
(Examples above demonstrate existing capabilities.)

ECOSTRESS

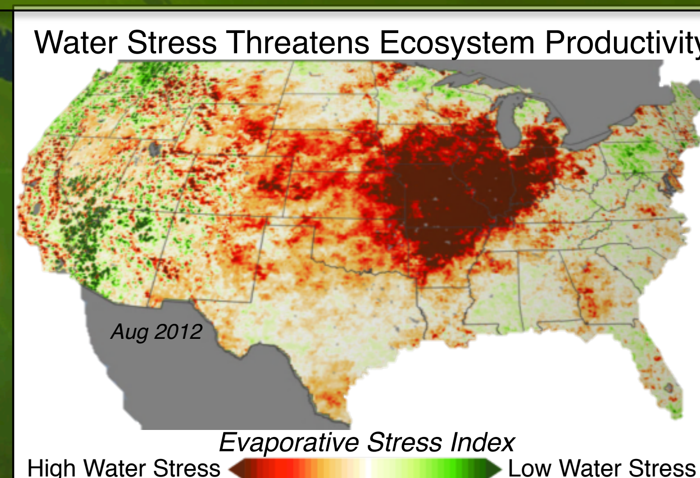
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

Dr. Simon J. Hook, JPL, Principal Investigator

*ECOSTRESS will provide critical insight into **plant-water dynamics** and how **ecosystems change with climate** via **high spatiotemporal** resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS).*



When stomata close, CO_2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

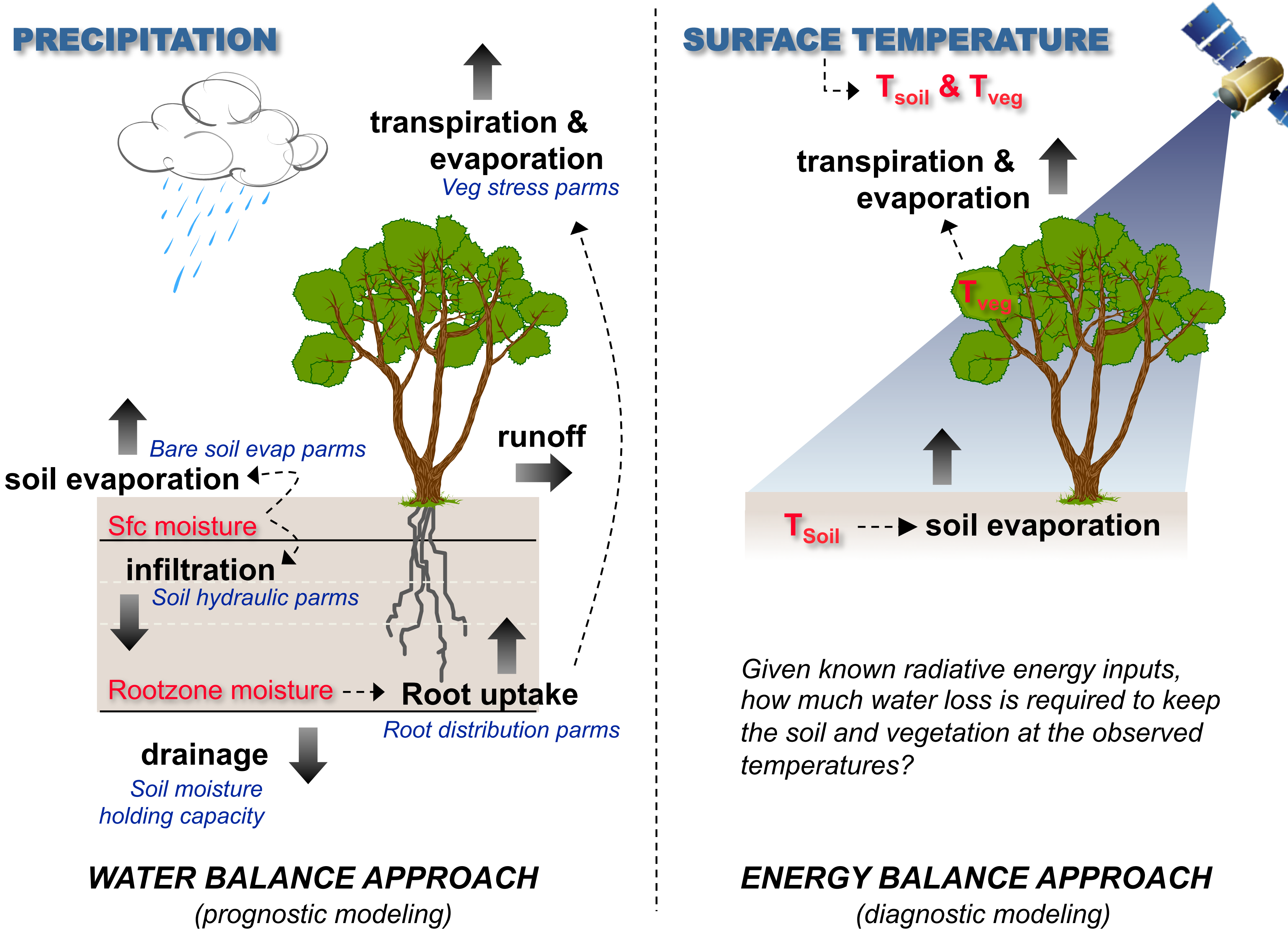


Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

Science Objectives

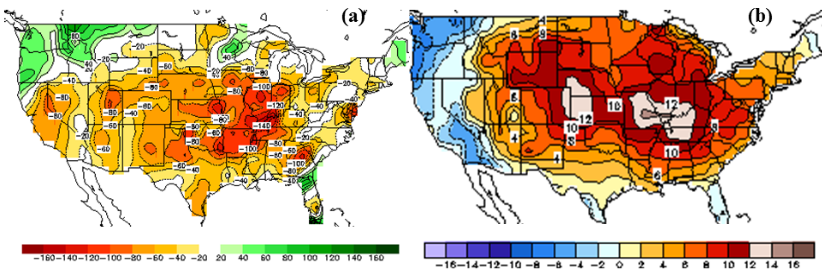
- Identify **critical thresholds of water use and water stress** in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant **water uptake decline** and/or cessation over the **diurnal cycle**
- Measure **agricultural water consumptive use** over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

Approaches to mapping ET

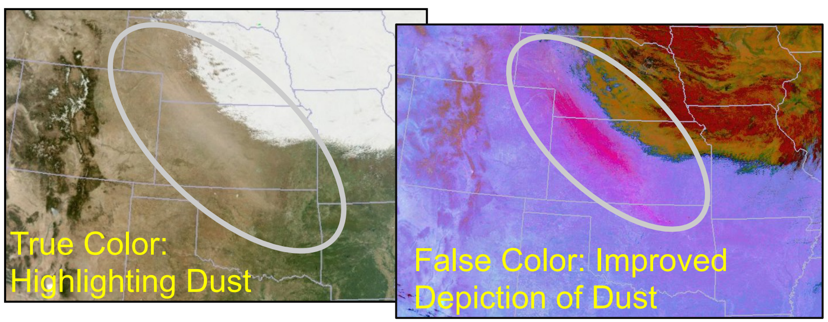


Martha C. Anderson, et al. *USDA-Agricultural Research Service, Hydrology and Remote Sensing Laboratory, Beltsville, MD*

NASA's Short-term Prediction Research and Transition (SPoRT) Center



Temperature and soil moisture anomalies for public health (extreme heat and cold) or environmental applications favorable for disease vectors



Multispectral remote sensing from VIIRS and MODIS for air quality and vegetation applications.

- The SPoRT Center focuses on the transition of "research to applications" for unique NASA, NOAA, and other-agency capabilities
- Current focus is on the use of land surface modeling and remote sensing for a variety of applications
  - Weather Analysis and Forecasting
  - Numerical Weather Prediction
  - Remote Sensing
  - Disasters
- SPoRT is well-suited to combine multiple products to support Public Health applications, through combination of satellite-derived and model-derived information.

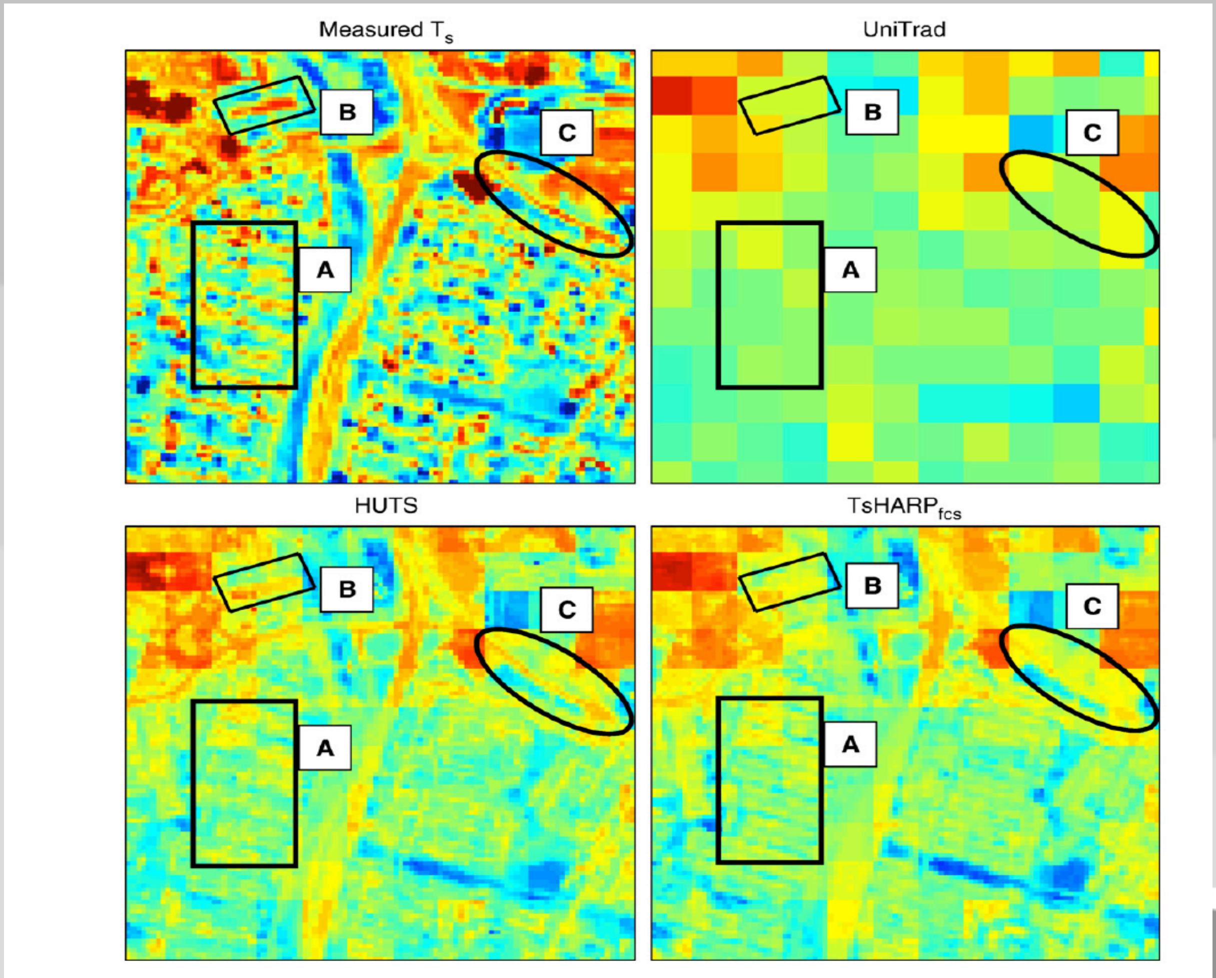
Combined, modeling and remote sensing capabilities can support the generation of new Public Health products, alerts, and end training for end users.

Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

High-resolution urban thermal sharpener (HUTS)

Anthony Dominguez [a], Jan Kleissl [a,*], Jeffrey C. Luvall [b], Douglas L. Rickman [b] 2011

[a] University of California, San Diego, Department of Mechanical and Aerospace Engineering, USA
[b] NASA, Marshall Space Flight Center, AL 35812, USA



KEY ATTRIBUTES OF THE SURVEILANCE AND MONITORING SYSTEM

(1) Determine the current and evolving state of malaria prevalence and incidence by analyzing, refining and validating existing and developed models;

(2) Provide training and courses designed to give professional and non-professional personnel an adequate knowledge of disciplines including entomology, parasitology, epidemiology, GIS/Remote sensing and computer technology.

(3) Guide the tailoring of intervention strategies to local landscape characteristics by integrating the implementation and analysis of multiple intervention tactics from environmental to clinical.

(4) Integrate climate, epidemiological and ecological data, to forecast critical potential high risk transmission areas and time periods.

(5) Analyze overall progress for households and communities, to determine health and economic implications associated with malaria reductions or increases.

(6) Identify and provide key data needs for operational managers, ministers of health, donors and scientific users.

(7) Measure the performance and cost effectiveness of malaria control and/or other interventions by performing periodic cost-benefit analyses.

(8) Expand the surveillance system to different provinces or landscapes within country.

(9) Ensure built-in adaptability of this system to other diseases of public health importance.

(10) An open IT system design to accommodate other data-bases, partners, and sources of information